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14. ABSTRACT
The electromagnetic spectrum has become increasingly crowded in recent years as a result of the demand for higher bandwidths for greater communication throughput and finer resolution radar imaging. Thus efficient use of bandwidth is essential to meet the needs of a wide variety of technological disciplines. For radar applications perhaps the greatest challenges to attaining high spectral efficiency are the need for spectrally clean emissions that minimize the out-of-band interference and the complementary need for advanced receiver designs to enable the separation and processing of multiple radar and communications signals that mutually interfere with one another. In essence, instead of dealing with interference as simply a deleterious effect, it can be exploited as additional sources of information without the requirement of additional bandwidth. This 'waveform diverse' perspective is used to facilitate numerous performance enhancements and new operating modes for sensing.

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General Program Overview

Research Tasks Achieved (chronological beginning with most recent)

- **MVDR Formulation for Gain-Constrained Adaptive Pulse Compression**
  The Minimum Variance Distortionless Response (MVDR) formulation has been employed as a possible alternative to the previous MMSE formulation with the goal of providing addtional robustness to ill-conditioning induced by very high dynamic range via the gain constraint of MVDR. It was determined that the MVDR framework provides only marginal additional robustness relative to MMSE. However, the reduced-dimension MMSE implementation, developed as a means to substantially reduce computational cost, realizes a marked improvement in stability when employing the MVDR formulation.
  1 Conference paper

- **Analysis of Range Super-Resolution Dependence on Radar Waveform Characteristics**
  Previous work on radar range super-resolution has relied solely on the use of continuous waveforms such as chirps. However, in this work it is shown how realistic discrete waveforms (*i.e.* possessing chip transitions that are not instantaneous) actually can provide better super-resolution performance. The fundamental reason for this improvement is that, for the same nominal range resolution, a discrete waveform possesses higher bandwidth than a continuous waveform due to the transitions between chips. If these transition regions are properly accounted for in the receive processing, the inherent higher bandwidth can be exploited to improve the resolution.
  1 Conference paper

- **Radar Pulse Compression Eclipsing Repair**
  For medium to high PRF radars, pulse eclipsing effects can results in significant losses. The eclipsing problem is a known weakness of optimal mismatched filtering approaches as the underlying model in which they are formulated does not accurately represent these eclipsed regions in range. A subtle modification to the MMSE-based Adaptive Pulse Compression (APC) algorithm has enabled it to accurately estimate the eclipsed regions. Furthermore, in so doing the general structure of APC implementation has changed to provide an overall improvement in estimation accuracy at all ranges.
  1 Conference paper

- **Direction-of-Arrival Estimation Tolerant to Temporal Correlation**
  It is well-known that temporal correlation of sources severely degrades the accuracy of DoA estimation techniques as they employ multiple time samples with which to estimate the spatial covariance matrix. A "single time sample" approach denoted as ReIterative Super-Resolution (RISR) has been developed that is effectively immune to temporal correlation effects thus providing accurate estimation of sources locations

regardless of temporal similarities. Non-coherent integration of time samples is likewise shown to further improve performance while maintaining the robustness to temporal correlation.
1 Journal paper (accepted) and *1 Conference paper*

- **Intra-Pulse Radar-Embedded Communications**
  A novel framework for low probability of intercept (LPI) communications has been mathematically formulated. Preliminary simulation results indicate that this type of approach has the potential to provide acceptable communication error-rate performance while maintaining covert signaling with a data-rate that is orders of magnitude higher than similar methods used for embedding identifiers in SAR images. Relevant to radar applications, the nature of this manner of communications may significantly improve radar front-end processing by providing real-time prior/feedback information of the illuminated region via covert side channels.
  1 Journal paper (accepted) and *2 Conference papers* (both Invited)

- **Hybrid Multistatic Receive Processing**
  The adaptive suppression of range sidelobe interference can be achieved by either cancellation (*i.e.* nulling) or subtraction (*e.g.* the CLEAN algorithm). In general, subtraction is more susceptible to propagation of mismatch errors, though it is not limited by finite adaptive degrees of freedom as is cancellation. A suite of adaptive algorithms have been developed that effectively combine cancellation and subtraction processing to exploit the intrinsic benefits of each. For a probability of detection of 0.9, simulated results have indicated a 10 dB sensitivity improvement for the detection of small scatterers masked by multistatic interference.
  1 Journal paper and *1 Conference paper* (Invited)

- **Effective Reduced-Dimension STAP**
  The meta-algorithm denoted as FRACTA has been implemented in a reduced-dimension framework to both reduce the deleterious effects of heterogeneous sample data and to facilitate computationally efficient operation. In addition, approximate prior knowledge based on a bald-Earth clutter model and known operating characteristics of the radar has been utilized to further compensate for data heterogeneity thereby enabling effective GMTI performance.
  1 Book chapter, 1 Journal paper, and *1 Conference paper*

- **Real-Time Implementation of Adaptive Pulse Compression**
  A reduced dimensionality version of the APC algorithm has been developed. The APC algorithm greatly increases radar sensitivity while still maintaining design freedom for the radar waveform. The reduced dimensionality version, denoted as Fast APC (FAPC) can conceivably achieve a computational reduction by a factor of as much as 100 and possibly making real-time operation feasible in current systems.
  1 Journal paper, *1 Conference paper,* and *1 Patent*
  ** EECS Best Master's Thesis Award for Thomas Higgins (now PhD student)*

- **Imaging of High-Speed Targets using a Single Pulse**
  Utilizing the Doppler shift of high-speed targets over the extent of a single pulse a recursive imaging algorithm denoted as Single Pulse Imaging (SPI) has been developed which far exceeds the rudimentary images that can be produced using the standard deterministic matched filter bank. The SPI algorithm imaging resolution provides nominal range resolution (~1/bandwidth) and coarse Doppler resolution that is limited by the temporal extent of the waveform.
  1 Journal paper and *1 Conference paper*

- **Doppler Compensation for Pulse Compression of High-Speed Target Returns**
  High-speed targets induce a Doppler shift on a reflected radar waveform that can result in a mismatch upon receive. This mismatch causes SNR loss at the matched point and also limits sidelobe suppression capability. To compensate for the effects of Doppler mismatch, a Doppler estimation mechanism has been incorporated into the Adaptive Pulse Compression (APC) framework. The resulting Doppler-Compensated APC (DC-APC) is expected to be particularly applicable to ballistic missile defense tracking after the separation phase.
  1 Journal paper and *1 Conference paper*

- **Combined Adaptive Pulse Compression and Adaptive Beamforming**
  Employing the adaptive receive structure developed for pulse compression, a novel algorithm has been developed with incorporates knowledge derived from adaptive range profile estimation into an adaptive beamformer to achieve greater spatial interference suppression.
  1 Journal paper and *1 Conference paper*

- **Generalized Multistatic Received Signal Modeling**
  A generalized framework has been developed for the reception of the return signals for multiple proximate radars operating concurrently in the same spectrum. This framework effectively accounts for all mainbeam and sidelobe transmission and all mainbeam and sidelobe reception thus providing substantial robustness to model mismatch. The resulting algorithm may alleviate much of the mutual interference effects currently being experienced by radars operating in the arid climates.
  1 Journal paper and *1 Conference paper*

- **Joint Spectral/Power-Efficient Radar Waveform Design**
  Previous methods to facilitate spectrally-clean radar transmission have either been limited to binary waveforms or necessitate amplitude modulation that complicates transmitter hardware and greatly reduces energy-on-target. A Continuous Phase Modulation (CPM) framework, typically employed for aeronautical telemetry, has been modified to enable transmission of polyphase radar codes in a way that that is both power efficient and spectrally efficient. The trade-off cost is some increase in range sidelobes when standard matched filtering is employed. However, Least-Squares mismatched filtering provides the needed sidelobe suppression on receive.
  1 Journal paper (in preparation) and *1 Conference paper*

- **Experimental Validation of Adaptive Pulse Compression**
  In collaboration with Karl Gerlach and Aaron Shackelford of the NRL Radar Division, experimental analysis has been performed utilizing the Adaptive Pulse Compression (APC) algorithm. Free-space experiments conducted at NRL demonstrate that APC performs very well on real measured data and uncovers scatterers that would be otherwise masked by standard receive processing. Ongoing experiments will address implementation on high power systems and also when multiple different radar waveforms are concurrently incident at the receiver (*i.e.* the RF fratricide problem).
  3 Conference papers

- **Transmit Array Diversity for Range-Coupled Beamforming**
  When different transmit array elements generate different radar waveforms, range and space become coupled thereby facilitating space-range processing on receive. The benefit of such coupling is higher dimensionality such as has been exploited for STAP techniques to enable isolation of the clutter space for subsequent cancellation. Note that this formulation can be viewed as a specific (and feasible) implementation of MIMO radar.
  2 Conference papers (1 published, 1 submitted)

- **Suppression of Near-Band Multistatic Radar Interference**
  A multistatic model for radars occupying contiguous spectral bands has been developed. This formulation may enable more compact frequency allocations among proximate radars. Furthermore, this model is directly applicable to monostatic synthetic wideband operation as an adaptive means to improve radar sensitivity for wideband sensing. The approach, based on some modifications to the previous multistatic algorithm MAPC, has been applied to measured data from the SPY-1 radar with excellent results.
  1 Conference paper

Waveform-Diverse Sensors

Research Justification

The electromagnetic spectrum has become increasingly crowded in recent years as a result of the demand for higher bandwidths for greater communication throughput and finer resolution radar imaging. Thus efficient use of bandwidth is essential to meet the needs of a wide variety of technological disciplines. For radar applications perhaps the greatest challenges to attaining high spectral efficiency are the need for spectrally clean emissions that minimize the out-of-band interference and the complementary need for advanced receiver designs to enable the separation and processing of multiple radar and communications signals that mutually interfere with one another. In essence, instead of dealing with interference as simply a deleterious effect, it can be exploited as additional sources of information without the requirement of additional bandwidth. This 'waveform diverse' perspective is expected to facilitate numerous performance enhancements and potentially new operating modes for sensing and communications.

Year 1 Accomplishments

In the first year of the program significant advancements were made in regard to improving radar sensitivity by cancelling both self-interference (range/Doppler pulse compression sidelobes) and mutual interference resulting from multistatic radar operation. In addition, substantial strides were made concerning the feasible implementation of adaptive pulse compression in current real-time systems.

In regard to multistatic radar operation, two different research tasks were successfully achieved. The first was the development of a generalized framework for the reception of the return signals for multiple proximate radars operating concurrently in the same spectrum. The general framework accounts for all mainbeam and sidelobe transmission and all mainbeam and sidelobe reception and thus incorporates all known and unknown array effects into the model. In addition, this framework eliminates the previous need for knowledge of the angle-of-arrival (AOA) of all received radar return signals. Only the AOA of the desired return signals are required. Hence, the general framework provides much greater robustness than the previous model. The resulting Minimum Mean-Square Error (MMSE)-based signal processing structure arising from this model has, in simulation, demonstrated orders-of-magnitude improvement in sensitivity over standard processing such as matched filtering and may significantly reduce the deleterious effects of mutual interference caused by ducting that have been recently reported (see R. Kniceley and G. Pilson, "Electro-Magnetic Interference to AN/SPY-1 During Operation Iraqi Freedom", Proc. *52nd Annual Tri-Service Radar Symposium*, MIT Lincoln Lab, Lexington, MA, 19-23 June, 2006).

The second completed research task related to multistatic radar is the combination of multistatic adaptive pulse compression (*i.e.* the MAPC algorithm) with adaptive beamforming. This combination enables the beamformer to utilize range-domain knowledge generated by MAPC to better reject spatial interference from other radars occupying the same spectrum. This improved spatial interference rejection in turn provides more available adaptive degrees-of-freedom to suppress range/Doppler sidelobes in the range domain. An example for 4 radars received from angles-of-arrival of +15°, +5°, −5°, and −15° relative to boresight is illustrated in Fig. 1. This work is one result from an ongoing effort to utilize numerous sources of diversity (spatial, frequency, temporal, polarization, etc) to achieve multistatic radar sensitivity at least as good as standard monostatic radar performance.

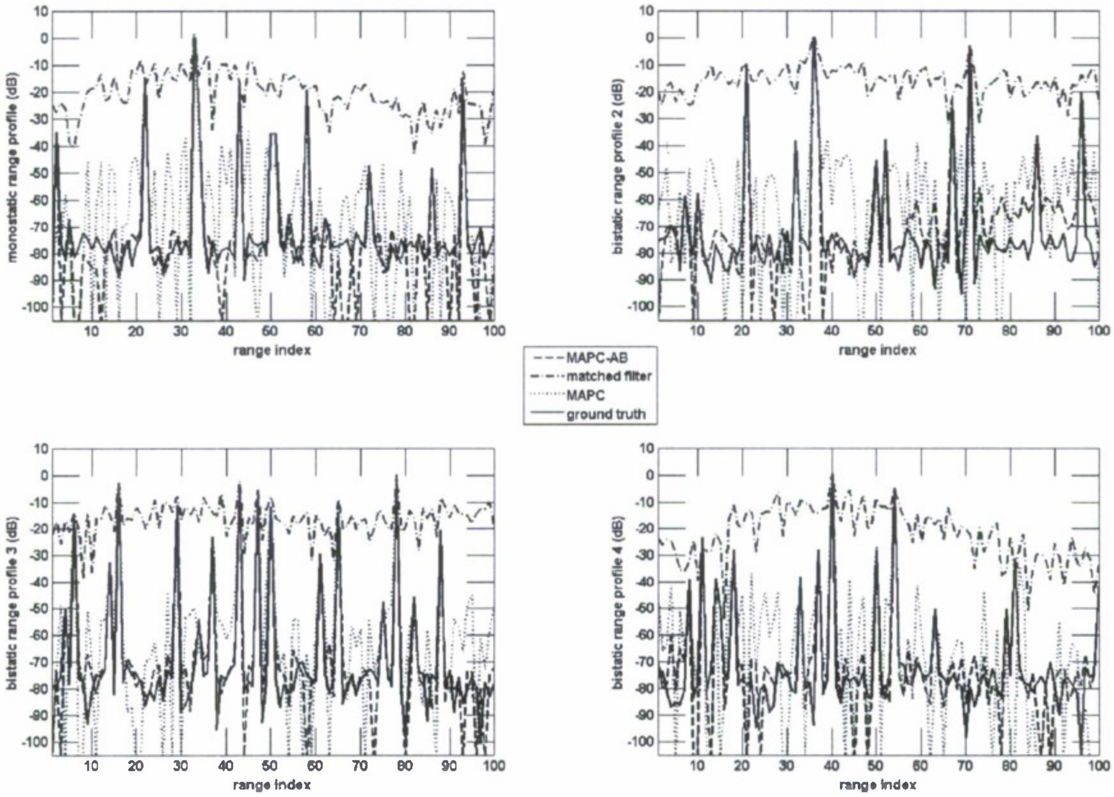

Fig. 1. Range profile estimates for 4 concurrently operating radars. MAPC estimation yields order-of-magnitude improvement over the matched filter. Joint range adaptive and beamforming (MAPC-AB) yields even greater improvement.

Another completed research task in Year 1 was the development of an imaging technique useful for high-speed targets. Utilizing the Doppler generated by high radial motion (for example, the blades of helicopter) over the temporal extent of a single pulse, the Single Pulse Imaging (SPI) algorithm is able to produce an image which possesses nominal range resolution (inversely proportional to the bandwidth) and Doppler resolution commensurate with a Doppler phase shift of π radians over the temporal extent of the waveform (2× better than a bank of Doppler shifted matched filters). The SPI algorithm suppresses the range and Doppler sidelobes in the image thus producing a much cleaner image than is possible with a similar bank of Doppler-shifted matched filters which, due to range/Doppler sidelobes, generates an image whereby lower power returns in the image are masked by large returns. An example for 5 targets (3 stationary and 2 with significant Doppler) is depicted in Fig. 2.

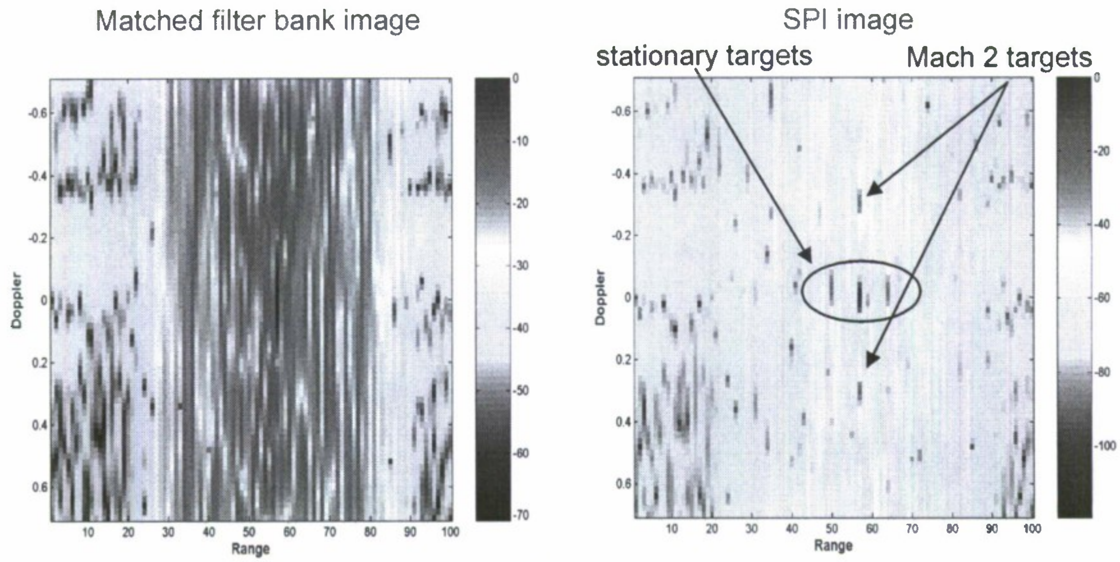

Fig. 2. Simulated imaging of a single 3.5 μs pulse at W-band

The final completed research task within the first year of the project was a highly efficient implementation strategy which may feasibly enable real-time operation of adaptive pulse compression in current radar systems. This strategy involves approximating the Minimum Mean-Square Error (MMSE) cost function, which the APC algorithm optimizes, into the sum of several lower-dimension independent cost functions. These lower-dimension cost functions are individually optimized and produce a resulting pulse compression filter that is very similar to the filter obtained by optimizing the full dimension cost function. Figure 3 below illustrates the relationship between the increase in computation relative to the matched filter and the sensitivity improvement.

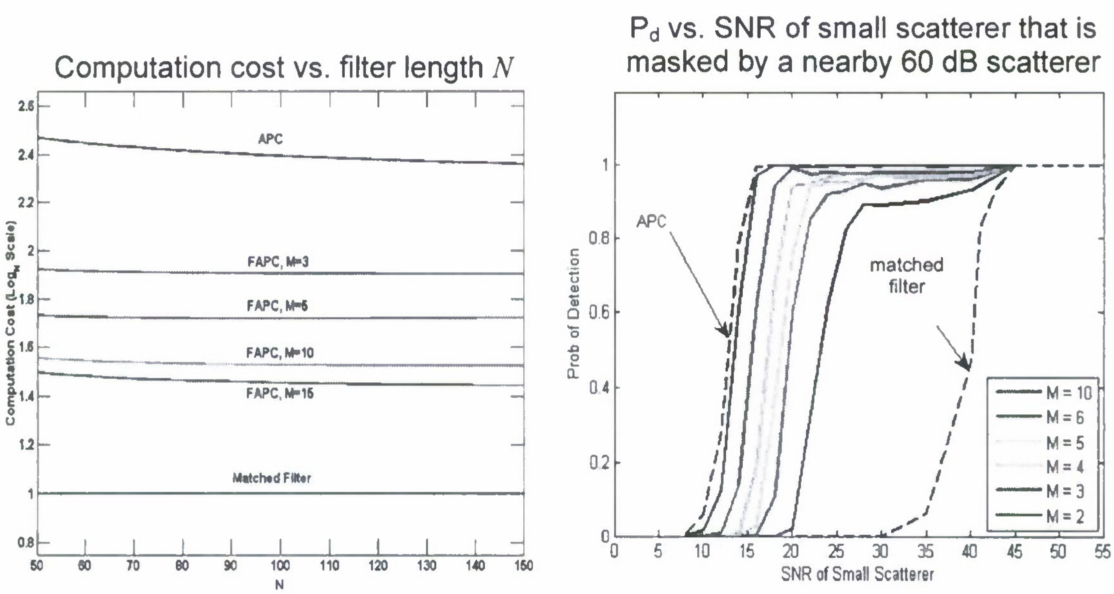

Fig. 3. Degree of computation increase relative to matched filter (left) is related to the sensitivity improvement (right)

Year 2 Accomplishments

In the second year of the program several additional significant accomplishments have been achieved. The first among these is the successful fusion of the interference suppression capability of the MAPC algorithm with the interference subtraction nature of the well-known CLEAN algorithm. The MAPC algorithm has been found to provide good range profile estimation as long as sufficient adaptive degrees-of-freedom are available to cancel the proximate interference sources (from nearby large scatterers). A multistatic version of CLEAN, denoted as bistatic-projection CLEAN (BP-CLEAN) has been devised that operates like CLEAN though only to remove the bistatic interference. Like its predecessor, BP-CLEAN is not constrained by degrees-of-freedom though it is implicitly limited by the often sub-optimal estimation accuracy of the matched filter. Appropriate combining of CLEAN and MAPC has yielded two hybrid methods denoted as Hybrid CLEAN-MAPC (HCLEAN-MAPC) and BPCLEAN-MAPC that provide significant improvement in radar sensitivity when in the presence of multistatic interference. For example, Fig. 4 depicts the probability of detection as a function of the SNR of a small scatterer illuminated by a monostatic radar that is masked by a large range-extended bistatic return from another radar (occupying J = 10 range cells). For P_d = 0.9, the hybrid approaches (HCLEAN-MAPC and BPCLEAN-MAPC) facilitate significant sensitivity improvement for the small scatterer versus MAPC or BP-CLEAN alone.

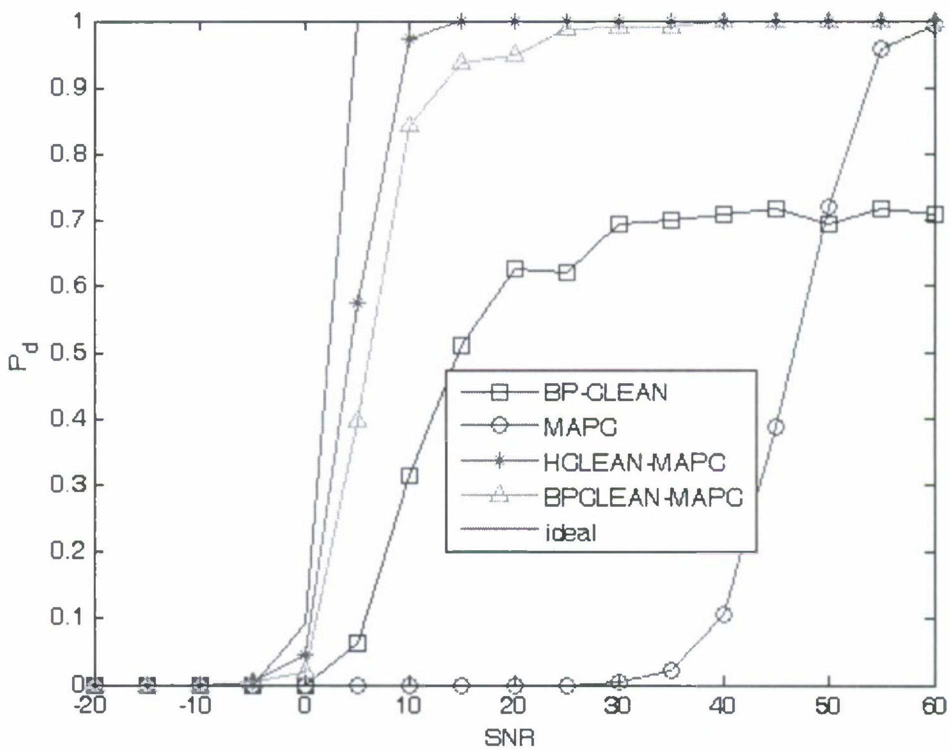

Figure 4. $\boldsymbol{P_d}$ **vs. SNR for** $\boldsymbol{J}$ **= 10 contiguous bistatic interferers with** $\mathbf{P_{fa}=10^{-6}}$

Another advance has been made in regard to the effective and robust STAP technique known as FRACTA. The FRACTA algorithm has been successfully implemented using existing dimensionality reduction techniques and has been found to maintain much of its previous high level of performance for airborne GMTI. The benefit of the reduced dimension implementation is the significant reduction in computational requirements as well as a marked reduction in the number of training data samples needed for convergence. Furthermore, approximate prior knowledge based on a bald-Earth clutter model has been utilized in conjunction with the reduced-dimension framework to provide additional robustness to sample starvation effects induced either by high data heterogeneity or as a by-product of the censoring process to avoid data contamination. The reduced-dimension and knowledge-aided instantiations of the FRACTA algorithm constituted a chapter in the recent book on *Knowledge-Based Radar Detection, Tracking, and Classification* edited by F. Gini and M. Rangaswamy and published by John Wiley & Sons, Inc.

In regard to improving radar pulse compression performance, two advancements were made in year 2. The first of these was the development of a subtle modification to the Adaptive Pulse Compression (APC) algorithm that enables the accurate estimation of the eclipsed regions in range. For medium to high PRF radars, where the pulse transmit time becomes a non-negligible portion of the pulse repetition interval (PRI), these eclipsed regions represent ranges at which substantial degradation in performance is typically observed for the ubiquitous mismatched filters as a result of mismatch in the models upon which these filters are based. In contrast, the Eclipsing-Repair APC (APC-ER) algorithm, by virtue of recursive updating of the range estimates in the eclipsed regions, has been found in simulation to provide a solution to this pervasive problem (note that similar results have been observed for experimental measured data at NRL). As an example, Fig. 5 depicts the performance of APC-ER (blue) in comparison with the optimum Least-Squares based mismatched filter (green) and the standard matched filter (red) relative to the ground truth (black). In the eclipsed regions at each end of the range profile the mismatched filter severely degrades while the APC-ER algorithm is able to suppress the sidelobes induced by the large eclipsed scatterers. In terms of Mean-Square Error (MSE) over the interval depicted, APC-ER provides 38 dB lower MSE than either the matched filter or the mismatched filter (due largely to the degradation in the eclipsed regions).

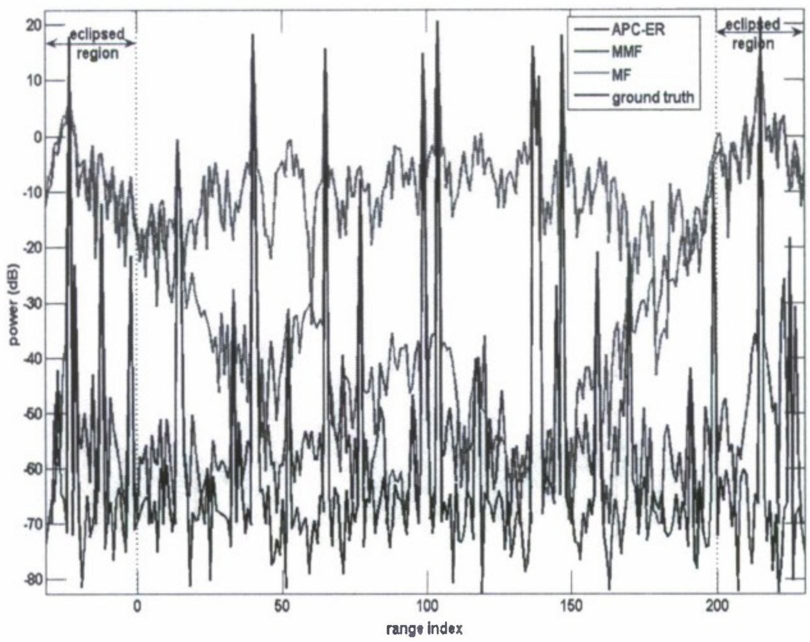

Fig 5. Range cell estimation performance for eclipsing in a dense scattering environment

The second development related to pulse compression improvement was an analysis of range super-resolution performance as a function of the nature of the transmitted waveform. Specifically, it was investigated how super-resolution using Least-Squares (LS) estimation and the Adaptive Pulse Compression (APC) method were influenced by the choice of either a continuous waveform or a realistic discrete waveform as all previous published efforts have only utilized continuous waveforms. With the nominal range resolution (determined by the matched filter) held constant, it is observed that the realistic discrete waveform (where finite transition regions have been properly included in the waveform model) has a higher bandwidth than the continuous waveforms due to the "extraneous" bandwidth resulting from the chip transitions. However, when employing receive filtering techniques capable of achieving super-resolution (LS and APC), it is observed that this extraneous bandwidth can be exploiting to provide better performance than is obtained with the continuous waveform. The modeling results from this effort have likewise been employed to develop robustness measures to combat range cell straddling losses with modest success.

Another significant development in the second year was the formulation of a novel framework for radar-embedded communications. Conceptually, this approach is vastly different from previous methods in that it involves the covert embedding of independent information on each individual radar pulse that is incident upon an illuminated RF tag/transponder. As such, data-rates commensurate with low-rate speech encoders (*e.g.* the DoD MELP codec) may feasibly be attained while maintaining a suitably low probability of intercept (LPI). However, the true benefit of such an approach is the potential capability of enabling access to prior/feedback information regarding the illuminated environment for the radar processing front-end via covert information provided by strategically placed sensors in the field. To date, a general mathematical optimization problem for the design of appropriate communication signals (waveforms) has been established along with the development of some preliminary waveform design approaches. Because of the expected depth of this line of research, it has transitioned to a separate theoretical/experimental program via an AFOSR Young Investigator Program (YIP) Award.

The final major research advance of the second year of the program was the development of a Direction-of-Arrival (DoA) estimator that is tolerant to temporal correlation between signal sources. Because traditional DoA estimators employ multiple time snapshots of the signal incident upon the array to form a spatial covariance matrix, severe degradation can occur when the spatially-separated signals are temporally correlated. Methods have been proposed in the past to ameliorate the effects of temporal correlation by utilizing sub-arraying techniques, though these approaches explicitly necessitate a reduction in spatial resolution. In contrast, the Re-Iterative Super-Resolution (RISR) algorithm employs the Reiterative MMSE framework in the spatial domain to enable DoA estimation for a single time snapshot of spatial samples. Furthermore, non-coherent integration over multiple time samples has been found to further improve performance via non-coherent SNR gain. As an example, Fig. 6 depicts the DoA estimation results for 3 equal-power temporally correlated sources with SNR = 30 dB for the well-known MUSIC algorithm, the spatially-smoothed MUSIC (SS-MUSIC) algorithm that is more robust to coherent sources, and 15 stages of the new RISR algorithm. The array has 10 antenna elements and 12 time samples are processed. Only the RISR algorithm is able to accurately estimate the DoA of the 4 sources.

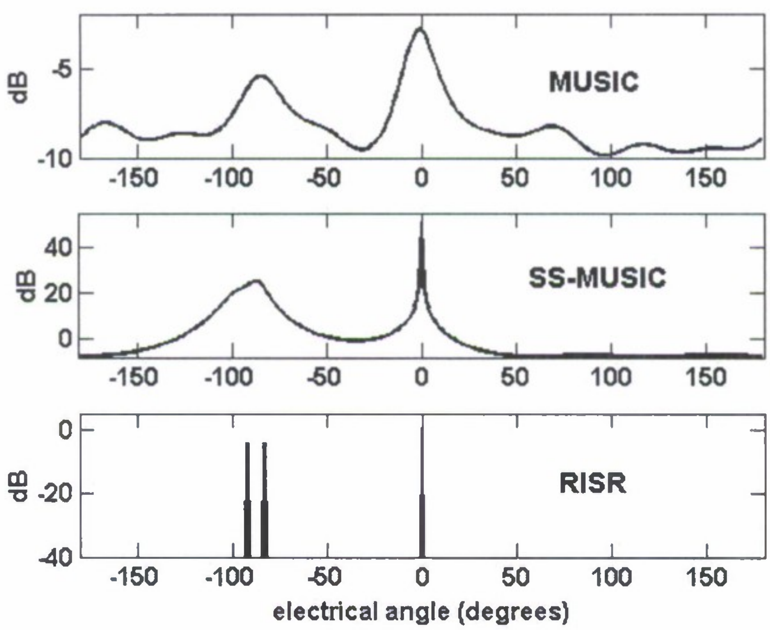

Figure 6. Correlated sources at electrical angles of –90°, –85.5°, and 0° (boresight), $N = 10$ antenna elements and $L = 12$ time samples

Year 3/4 Accomplishments

In the third and fourth years of the project (the fourth was a partial year due to no-cost extension) the focus has shifted somewhat from the investigation of advanced receive techniques to the exploration of new transmit structures that may facilitate enhanced performance. Two such transmit structures have been developed thus far. The first is a radar waveform design framework to jointly achieve power efficiency (*i.e.* maintain constant modulus) and spectrum efficiency, otherwise known as spectrally-clean. Many current systems use either differential phase shift keying (DPSK) or minimum shift keying (MSK) as a means to implement binary-coded radar waveforms with at least some suppression of out-of-band spectral leakage relative to the spectral content of theoretically "ideal" radar codes (*i.e.* instantaneous transitions between chips). However, DPSK and MSK implementations are not amenable to arbitrary polyphase waveforms. Alternatively, "kernel-based" spectrally-clean methods have recently been developed at NRL that are applicable to any waveform. However, the kernel-based approaches result in amplitude modulation of the waveform which necessitates more complicated transmitter hardware implementation and also induces loss of transmit power thereby yielding less energy-on-target. To accommodate arbitrary waveforms while maintaining constant modulus the Continuous Phase Modulation (CPM) framework employed for aeronautical telemetry has been used as a general waveform implementation structure. In addition to the CPM-based implementation, amplitude tapering of the first and last chips of the code to compensate for the rapid rise-time/fall-time of the pulse has been found to provide additional spectral containment. Figure 7 illustrates the spectral content of a 64-chip binary minimum peak sidelobe (MPS) code when Tukey weighting is used to taper the first and last chips (but flat otherwise over the code). Figure 8 depicts the range sidelobes performance when Least-Squares mismatched filtering is used on receive.

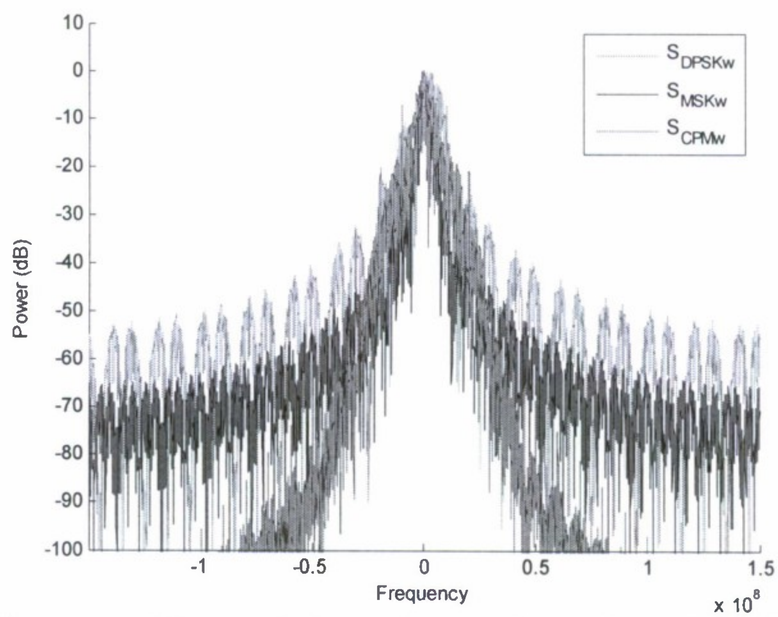

Figure 7 – Spectrum of Tukey windowed baseband waveforms for DPSK, MSK, and CPM implementations.

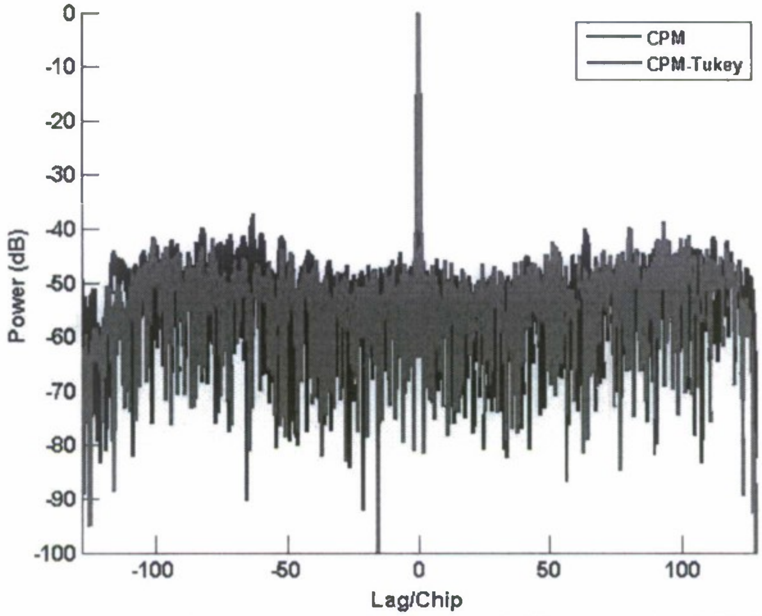

Figure 8 – Application of over-sampled mismatch filters to the CPM and CPM-Tukey (tapered) waveforms

Another transmit structure that has been explored is the transmission of different waveforms on different elements of a co-located antenna array which may be viewed as a special case of MIMO radar. Specifically, we consider the range-angle coupling that is induced when an incremental frequency shift is present across the array elements such as that proposed by Antonik and Wicks and denoted as a 'frequency-diverse array'. Preliminary work has shown that the beam curvature caused by range-angle coupling can be predicted in the same manner as for uncoupled beamforming. This effort has more recently been applied to the pulsed waveform structure to develop a signal model for space-range coupling. This model allows one to predict the resulting waveform that forms in space for a given angular direction and is then reflected back to the radar. The result is that the reflections from different directions are "tuned" to different temporal waveforms thus affording the possibility of better clutter cancellation as well as robustness to repeater jammers in the transmit sidelobes.

Four major accomplishments regarding receive processing have also been realized in years 3/4. The first concerns the collaborative effort with the NRL Radar Division to experimentally validate the Adaptive Pulse Compression (APC) algorithm. The APC algorithm has been demonstrated on measured data collected at NRL to suppress range sidelobes better than the standard processing. It has likewise been demonstrated that sidelobes in the pulse eclipsed regions can be suppressed so as to uncover masked, eclipsed targets. Also, the fast APC (FAPC) implementation that requires considerably lower computation has also been demonstrated to be effective on measured data. In addition, a version of APC has been applied to measured data collected from the SPY-1 radar using frequency-shifted sub-pulses and has again proven successful. Finally, preliminary work has indicated that the APC formulation is capable of effectively separating the concurrent returns from at least two multistatic radars.

The other major receiver-oriented accomplishment is the development of an alternative formulation for adaptive pulse compression based on minimum variance distortionless response (MVDR) estimation which is a gain-constrained version of MMSE estimation. The goal of this line of research was to provide additional robustness to ill-conditioning induced by high dynamic range of return signals that have necessitated previous robustness measures for APC. The MVDR framework has been found to provide marginal additional robustness relative to APC. However, the real benefit of the MVDR framework was realized for the fast APC (FAPC) algorithm because the intrinsic dimensionality reduction can produce some stability issues as FAPC only employs a subset of the elements of the signal covariance matrix.

Research Documentation & Awards (chronological in each category)

Awards/Honors

1. KU Miller Professional Development Award for Research (May 2008)

2. Richard K. & Wilma S. Moore Master's Thesis Award received by PhD student Thomas Higgins (for development of the Fast APC algorithm)

3. Invitation to join the Editorial Board for IET Radar, Sonar, & Navigation (Apr 2008)

4. Invitation to become Associate Editor for IEEE Trans. Aerospace & Electronic Systems (Jan 2008)

5. Air Force Office of Scientific Research (AFOSR) Young Investigator Award (Oct 2007)

6. Invitation to become a member of the IEEE AESS Radar Systems Panel (Oct 2007)

7. Elevation to IEEE Senior Member (Oct 2007)

8. 2007 NRL Alan Berman Research Publication Award

9. 2006 NRL Alan Berman Research Publication Award (lead author)

Books

1. *Applications and Methods of Waveform Diversity*, eds. M. Wicks, E. Mokole, S.D. Blunt, V. Amuso, and R. Schneible, SciTech Publishing, 2010. (in preparation)

Book Chapters

1. Chapter 7, "STAP via Knowledge-Aided Covariance Estimation and the FRACTA Algorithm," S.D. Blunt, K. Gerlach, M. Rangaswamy, and A.K. Shackelford, in *Knowledge Based Radar Detection, Tracking, and Classification*, ed. Fulvio Gini and Muralidhar Rangaswamy, John Wiley & Sons, Inc., New York, 2008.

Journal

1. S.D. Blunt, K. Gerlach, and E. Mokole, "Spectrum and Power Efficient Implementation for Polyphase Radar Codes," in preparation for *IEEE Trans. Aerospace & Electronic Systems.*

2. T. Higgins, S.D. Blunt, K. Gerlach, and E. Mokole, "Gain-Constrained Adaptive Pulse Compression for Synthetic Wideband Radar," in preparation for *IET Radar, Sonar & Navigation.*

3. T. Higgins and S.D. Blunt, "Space-Range Coupled Adaptive Receive Processing," in preparation for *IEEE Trans. Aerospace & Electronic Systems.*

4. S.D. Blunt, P. Yatham, and J. Stiles, "Intra-Pulse Radar-Embedded Communications," accepted to *IEEE Trans. Aerospace & Electronic Systems.*

5. S.D. Blunt, T.P. Chan, and K. Gerlach, "Correlation-Tolerant DOA Determination using Reiterative MMSE Estimation," accepted to *IEEE Trans. Aerospace & Electronic Systems.*

6. S.D. Blunt and T. Higgins, "Dimensionality Reduction Techniques for Efficient Adaptive Radar Pulse Compression," accepted to *IEEE Trans. Aerospace & Electronic Systems.*

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Invited Presentations

1. "Radar-Embedded Communications," *Waveform Diversity Workshop at Tri-Service Radar Symposium*, Monterey, CA, June 23-27, 2008.

2. "Hybrid adaptive receive processing for multistatic radar," *2nd International Workshop on Computational Advances in Multi-Sensor Adaptive Processing*, St. Thomas, U.S. Virgin Islands, Dec. 12-14, 2007.

3. "Diversity Aspects of Radar-Embedded Communications," *IEEE International Conference on Electromagnetics in Advanced Applications*, Turino, Italy, Sept. 17-21, 2007.

4. "Waveform Design for Radar-Embedded Communications," *2007 International Waveform Diversity & Design Conference*, Pisa, Italy, pp. 214-218, June 4-8, 2007.

5. "The Adaptive Pulse Compression Concept," *14^{th} Workshop on Adaptive Sensor Array Processing*, MIT Lincoln Laboratory, Lexington, MA, June 6-7, 2006.

Research Collaborations

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